NATIONAL COASTAL RESOURCES RESEARCH AND DEVELOPMENT INSTITUTE (PreliminaryProposal)_PRINCIPAL INVESTIGATOR: Dr. Michael Rozengurt

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PROJECT TITLE: Development of a Physical Model of a Salinity Restraining Channel to Control Salinity into Estuaries. Case of Study: San Francisco Bay

STATEMENT OF ISSUE OR PROBLEM: The intrusion of sea water into estuaries and river deltas has become a major cause of salinization of delta-estuary ecosystems in the United States and throughout the world. Increasing amounts of fresh waters are being diverted from rivers and deltas for agricultural, municipal and industrial uses and thus, estuaries such as San Francisco Bay have experienced up to a 65 percent loss in fresh water inflows which used to serve to "flush" the Bay from salt accumulated in the basin due to sea water intrusion and agricultural and municipal drainage water discharges. Increases in salinity adversely affect fish spawning, nursery and habitat areas. Fresh water withdrawals also modify velocity distributions in in the waterways, thus altering patterns of sediment transport and pollutant dispersion; drinking water supplies are also affected as brackish water moves inland to fill adjacent wells and fresh water aquifers; and agricultural production is negatively impacted as reduced quality of irrigation water leads to the loss of croplands.

The case of San Francisco Bay is a typical example of such development. Since 1944 nearly 400 million acre-feet of water has been diverted from the Sacramento-San Joaquin Delta resulting in salt water intrusion into the Delta. Thus, the quality of agricultural water derived from the Delta has declined significantly. Furthermore, Contra Costa County which pumps its water supply for over 300,000 residents from the Delta has experienced a serious decline in the quality of their drinking water. The increase in salinity and decreased flows to San Francisco Bay has also seriously affected the fisheries in the region. Sport catches of salmon, striped bass and shad have declined to as little as 10-30 percent of levels of 20 years ago despite a great increase in sport fishing effort, improved treatment of sewage discharges, and massive hatchery releases.

Other estuaries/deltas that have experienced degradation problems due to salt water intrusion include the Mississippi River Delta where salt water has recently intruded as far upstream as the intakes for New Orleans' water supply. Texas lagoons/estuaries have also experienced a serious water quality decline due to salt water intrusion as have the Nile River in Africa and the Sea of Azov in the USSR.

The purpose of the investigation proposed herein is to develop one specific solution concept for the restraining of salinity in estuaries: the Salinity Restraining Channel

(SRC). Preliminary studies have shown that the SRC can be an effective, non-intrusive method of preventing salinity from reaching unacceptable levels. The channel operates on the basis of well defined hydraulic principles and is compatible with natural fish migration, sediment load transport and navigation requirements.

The proposed channel (figures 1,2) will have walls above the high-high tidal level and will be built with a channel width and depth that is suitable for navigation. The overall hydraulic resistance of the channel can be increased by induced turbulence and enhanced energy dissipation through the emplacement of certain structures on the bottom and walls of the structure.

HOW WILL THE STUDY BE USED: This study will be used to assist environmental planners, managers and scientists in assessing the viability and practicality of using the SRC as a method to control salt water intrusion into estuaries. The collection and analysis of data related to the problem of salinity intrusion in the San Francisco Bay estuary will provide a sound basis for the formulation and experimental development of the restraining channel concept and will also answer important environmental questions with immediate practical applications. The establishment of statistically validated river and delta flow regimes needed to protect the chemical quality of water and the balance of the ecosystem will provide policy makers with an important planning tool; it will allow a rational determination of acceptable levels of seasonal and annual freshwater diversions, which will in turn lead to a reassessment of agricultural, industrial and municipal water uses. Those who may benefit from the project include :

* The State of California and its water planners, environmental engineers, and biologists (Bureau of Reclamation, Department of Water Resources, Department of Fish and Game).
* Federal Agencies charged with the regulation of waterways and natural resources (U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Fish and Wildlife Service).
* Environmental organizations, both public and private (Regional Water Quality Boards, Sierra Club, Oceanic Society, Save San Francisco Bay Association).

OVERALL PROJECT GOAL: The proposed investigation will establish the viability of the Salinity Restraining Channel as a means of protecting estuarine environments, the Sacramento/San Joaquin Delta and upper San Francisco Bay estuary in particular, from further degradation due to salt intrusion. The project will use San Francisco Bay estuary as an example but generalized formulations will also be developed to allow implementation of the SRC concept in any estuary. Some of the benefits associated with the development of a salt restraining will be enhanced water quality and fisheries in the estuary, enhanced water quality in adjacent wells and aquifers, increased irrigation water quality and the potential of increased diversions without further negative impact on the estuary. This work will also lead to an improved understanding of the mechanics of salt water intrusion in estuaries and to the improvement of numerical hydrodynamic and salinity models which will prove to be useful to both researchers and educators who deal with coastal environments.

APPROACH TO BE USED: A two year study is proposed for the development of a physical model of a salinity restraining channel for the upper San Francisco Bay. (1) The first year will focus on the gathering and analysis of necessary data, the assessment of salt intrusion mechanisms, the definition of parameters related to the restraining channel and the derivation of empirical and theoretical expressions to define the interaction of the salinity restraining channel with its estuarine environment. (2) The second year will be devoted primarily to the experimental evaluation of the SRC concept, the assessment of study findings and reformulation of governing equations, and the documentation and dissemination of the results of the investigation.

The data gathering and analysis will have as its primary aims :

* The evaluation and comparison of watershed and discharge variables for unimpaired and regulated conditions of river inflow and delta outflow.

* The development of statistical basis for making freshwater availability predictions.

* The statistical analysis of the relationship between freshwater diversion and salt intrusion in the delta.

* The development of a statistical basis for determining the effects of seasonal freshwater diversions from the river watershed , and for relating tolerance levels of biota to salt concentration fluctuations.

* The definition of horizontal and vertical velocity distribution s at various locations within the Bay, particularly in the Carquinez strait, where the salinity restraining channel will be initially tested.

* The selection of tidal hydrodynamic and salinity models applicable to the San Francisco Bay estuary, and their calibration and verification.

The analytical study of the salinity restraining channel will have as its primary aim the formulation of equations governing the dynamics of the channel's interaction with the environment. The ultimate goal will be reached progressively as the various oceanographic and hydrodynamic parameters are individually examined and their correlation established. The data compiled for the San Francisco Bay estuary will be used as a basis for the theoretical definition of the SRC.

Research tasks that will be undertaken to theoretically define a salinity restraining channel applicable to the San Francisco Bay estuary include:

* Assessment of the scale of seasonal mechanisms of water and salt exchange within the ecosystem to establish the laws governing the dynamics of salt intrusion parameters.

* Assessment of the effects of impermeable internal barriers within the Carquinez Strait on tidal fluctuations and salinity levels in Suisun Bay, to define theoretically advantageous geometric configurations for the restraining channel.

* Assessment of hydraulic and structural design requirements for the salinity restraining channel, to define its potential effects on navigation, sediment movement, and Carquinez Strait bathymetry.

* Derivation of equations to predict the effects of variable SRC configuration on salt intrusion into the delta for different rates of freshwater discharge.

* Derivation of equations to predict salt content stabilization time for the San Francisco Bay estuary relative to different rates of freshwater discharge.

PROOF OF SERVICE BY MAIL

(C.C.P. 1013a, 2015.5)

I declare that:

I am employed in the County of San Francisco, State of California. I am over the age of eighteen years and not a party to the within action. My business address is 3150 Paradise Drive, Tiburon Center for Environmental Studies, San Francisco State University, California, 94920.

On February 1, 1988 I served the attached PHASE I: CLOSING BRIEF FOR THE SAN FRANCISCO BAY-DELTA HEARING thereof in a sealed envelope, with postage prepaid, in the United States mail at San Francisco, San Francisco County, California, addressed as follows:

SEE ATTACHED EXHIBIT A - "MAILING LIST"

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct and that this declaration was executed on February 1, 1988 at San Francisco, California.

M. Rozengurt

Michael A. Rozengurt, Ph.D

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

IN THE MATTER OF

PHASE I OF THE BAY-DELTA ESTUARY HEARINGS

(CLOSING BRIEF OF THE ROMBERG TIBURON CENTER FOR ENVIRONMENTAL STUDIES)

The Romberg Tiburon Center for Environmental Studies submits as its closing brief the following proposed findings of fact derived from the exhibits and testimony which it has sponsored.

M. Rozengurt

THE PAUL F. ROMBERG
TIBURON CENTER FOR ENVIRONMENTAL STUDIES
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CLOSING BRIEF:
FINDINGS OF FACT & RECOMMENDATIONS FOR THE BAY-DELTA HEARINGS

Michael A. Rozengurt, Michael J. Herz & Feld, S.A.

For the past three years the Romberg Tiburon Center (TCES) has conducted a program of research designed to:

(1) Describe and evaluate freshwater inflow to the Delta and San Francisco Bay and the manner in which flow has been modified since the early part of the century (especially since the construction of the Central Valley and State Water Projects);

(2) Examine the relationship between modifications in flow and associated changes in the fishery resources of the system;

(3) Develop data-based recommendations regarding the quantity of freshwater required to maintain the health of this important estuary.

Because there existed no other detailed evaluation of water supply to the Delta and San Francisco Bay or any investigation of the relationship between flow and fisheries resources, this information was developed for presentation to the State Water Resources Control Board as part of the Bay-Delta Hearings, as well as for use by other government agencies concerned with decision making for this estuary, and by other interested parties.

The results of this research have been presented in reports submitted as hearing exhibits:

Rozengurt, M., Herz, M.J., & Feld, S. 1987. Analysis of the Influence of Water Withdrawal on Runoff to the Delta-San Francisco Bay Ecosystem (1921-1983), Romberg Tiburon Center for Environmental Studies Technical Report No. 87-7. (TCES Exhibit # 1)

Rozengurt, M.J., Herz, M.J., & Feld, S.A. 1987 The Impact of Freshwater Diversions on the Ecosystem of the Delta & San Francisco Bay: An Inventory of Questions on the Status of Knowledge. (TCES Exhibit # 2)

Rozengurt, M., Herz, M.J., & Feld, S. 1987. The Role of Water Diversions in the Decline of Fisheries of the Delta-San Francisco Bay & Other Estuaries, Romberg Tiburon Center for Environmental Studies Technical Report Number 87-8. (TCES Exhibit # 20)

Leopold, L.B. 1987. Sacramento Delta Water Supply and Review of the Tiburon Center Report. Unpublished. (TCES Exhibit # 22.

Rozengurt, M.A., Herz, M.J., & Josselyn, M. 1987. The impact of water diversions on the river-delta-estuary-sea ecosystems of San Francisco Bay and the Sea of Azov. In D.M. Goodrich (Ed.), San Franccisco Bay: Issues, Resources, Status, and Management. Washington, D.C.: NOAA Estuarine Programs Office, NOAA Estuary-of-the-Month Seminar Series No. 6, 35-62. (TCES Exhibit # 23)

Rozengurt, M.A., & Herz, M.J. 1987. The effects of fresh-water diversion on the fisheries, flushing and health of San Francisco Bay and the Sea of Azov. In _Managing Inflows to California's Bays and Estuaries_. Sausalito, CA, The Bay Institute. (TCES Exhibit # 24)

Much of the data contained in these reports, as well as additional information, was presented before the State Board as testimony (or elaborated upon in cross examination; Hydrology, July 14, 1987, Hearing Volume 5A; Impacts of Freshwater Inflow on San Francisco Bay, December 9, 1987, Hearing Volume 56).

The most relevant findings from this research program are:

Modifications in Freshwater Flow to the Delta & San Francisco Bay

(1) Since 1967, annual diversions have reduced natural Delta outflow to San Francisco Bay (1921-1978 mean = 27.2. MAF) by as much as 60%. These maximum annual withdrawals (14-21 MAF) are 3-5 times higher than before completion of major components of the CVP and SWP. (TCES Exhibit # 1, pages II.7, IV.2)

(2) For the spring -- the most critical period for providing optimal physical, biological and biochemical conditions for maintaining fisheries resources in the estuary and water quality in the Delta-Bay ecosystem -- up to 85% of the freshwater inflow has been diverted in some spring months for use outside the basin. (TCES Exhibit # 1, page IV.3)

(3) As a rule, since the construction of the major water projects, the largest percentages of freshwater flow are diverted in years of subnormal and critical wetness. Although the absolute quantities of water withdrawn in these dry years are much less than diversions in normal years, the impacts are greater. (TCES Exhibit # 1, page II.11)

(4) Overall, spring water supply (for 5-year periods), which normally fluctuates within +/- 25% of its long-term average in this and most other estuaries, is currently one third the levels prior to CVP/SWP construction. Would-be-normal flow conditions are currently characterized by negative deviations of -40 to -85%. (TCES Exhibit # 1, page III.29)

(5) Between 1967 and 1984, residual spring outflows to San Francisco Bay were equivalent to unimpaired flows in years of subnormal, dry or critical years (1.5-2.5 MAF/mo). (TCES Exhibit # 1, page IV.6)

(6) As a result of excessive water diversions since the beginning of project operations (1944-1983), the cumulative quantity of water not reaching San Francisco Bay is 366 MAF (60 times the volume of the Bay). (TCES Exhibit # 2, page 60)

(7) In the post project period, diversions which previously occurred only in the spring are made throughout the year. (TCES Exhibit # 1, page IV.7)

(8) Annual and spring low flow events which happened only rarely under unregulated conditions have now become the predominant events for the system, occurring on an almost annual basis, except in very wet years. (TCES Exhibit # 20, page 56)

(9) Since the beginning of CVP/SWP operation, the number of years in which inflow is considered wet has decreased from natural conditions from 30% of all years to 15% of years while the number of critically dry years has increased from 14% of all years to 39%. Thus diversions and depletion under present conditions have doubled the number of years considered critically dry. (TCES Exhibit # 22, page 5)

(10) The amount of water permitted to be diverted each year depends upon the water year-type (e.g., wet, dry, critical). Current decisions regarding water distribution in California are based upon the Four River Index system, a year-type classification system which excludes 25% of the Sacramento-San Joaquin watershed, which represents only 61% of the normal river inflow to the Delta. This system has resulted in overestimates of water availability and has therefore permitted excessive diversions. (TCES Exhibit # I, page I.46-50; TCES Exhibit # 20, page 41 & Figure 3-1; December 9, 1987 Hearing Record, Volume 56, pages 83-86)

Relationship Between Flow Modification & Fisheries Decline

(1) For the 1916-1931 period (when the Delta and Bay were still relatively healthy and could support significant commercial fisheries), salmon catch was highly correlated with both annual and spring regulated outflows to the Delta 3-5 years earlier ($r = 0.80-0.97$, $p<.01$). Successful catches occurred with annual flows of 19-23 MAF and mean spring monthly runoff (April + May + June/3) of 2.5-4.0 MAF. (TCES Exhibit # 20, pages 81 and 87).

(2) In the post-project period, the number of fall-run salmon returning to spawn at the Red Bluff Dam was highly correlated with annual and spring regulated Delta outflow 3-5 years earlier. Successful migration appears to require mean annual flows of 17-19 MAF and mean spring monthly flows of 2.3-2.8 MAF for several successive years. (TCES Exhibit # 20, pages 93, 95, 96)

(3) For the 1916-1935 period, high correlations were found between commercial catches of striped bass and both annual and spring Delta outflows 3-5 years earlier. (TCES Exhibit # 20, pages 110, 111)

(4) Similar relationships were found for party boat catches of striped bass and flows lagged by 3 years for the 1944-1985 period. For both the early commercial period and the later party boat era, optimal catches were observed with annual flows of 17-22 MAF and spring monthly flows of 2.0-3.4 MAF. (TCES Exhibit # 20,pages 116, 119, 121)

(5) High correlations were also observed between commercial catches of American shad (1916-1931) and annual (20-25 MAF) and mean spring monthly (2.5-3.5 MAF) flow 3-5 years earlier. (TCES # 20, pages 128-130)

(6) Correlations alone do not "prove" that highly correlated events are causally related, i.e., that the amount of available water determines the magnitude of catch or level of productivity. However, when a variety of measures such as commercial and party boat catch in three different fish species, data from both pre- and post-water project construction, and other measures of fish production (striped bass index, salmon spawning migration) all correlate significantly with Delta outflow 3-5 years earlier, the likelihood of there being a causal relationship between these factors is greatly enhanced. Such associations have been obtained in many other estuaries and are widely accepted as evidence that freshwater inflow is the principal factor in estuarine health and fish production. (TCES Exhibit # 20, page 20-28, Figures 2-1 & 2-7, Hearing Record, December 9, 1987, Volume 56, pages 66-67, 118

Conclusions

(1) In general, for the pre-project period, optimal commercial salmon, striped bass and shad catches were obtained when total spring regulated Delta outflow was 6.9-10.5 MAF and annual regulated Delta outflow was 19-22 MAF. (These conditions represent 64-97% of the normal, unimpaired spring and 70-81% of annual Delta outflow (normal = 10.8 and 27.2 MAF, respectively, for the 1921-1978 period.) (TCES Exhibit # 20, page 143)

(2) For the post-project period, the high correlations between production indices (salmon fall run, Striped Bass Index, striped bass party boat catch) and average spring and annual regulated Delta outflow for several consecutive years of the post-project period (1944-1985) suggest that the health and productivity of the Delta and Bay can best be maintained with mean monthly spring flows of 2.3-2.5 MAF (38,655-42,014 cfs) and annual Delta outflows of 17-19 MAF for periods of 3 to 5 years (64-70% and 62-70% of spring and annual unregulated flows - 1921-1978 averages = 3.6 and 27.2 MAF, respectively). (TCES Exhibit # 20, page 144)

(3) Deterioration of the San Francisco Bay estuarine system and its living resources (decreases in fish catches and population levels) started in the late 1960s and became obvious in the late 1970s, when flows were reduced to mean spring monthly levels of 1.0-1.5 MAF and mean annual flows of 11-15 MAF (27-42% and 40-55% of their respective unregulated 1921-1978 averages). (TCES Exhibit # 20 ,pages 26, 27, 144)

Recommended Flows for Preservation & Maintenance of the River-Delta-Bay Ecosystem & Its Living Resources

Based on this evaluation of modifications in regulated flows and their impacts on salmon, striped bass and shad populations and catches in the Delta and San Francisco Bay, we propose the following criteria for mean spring and annual regulated Delta outflows which must be maintained for periods of at least 2-3 consecutive years to ensure adequate water quality, seasonal displacement of the entrapment zone and optimal conditions for fish migration and spawning, larvae, egg and juvenile survival, and catch success in the Delta and San Francisco Bay (sport and recreational) and the coastal zone of the Gulf of the Farallones (sport, recreational and commercial):

Total Spring Regulated Delta Outflow (RDO)	**6.9-7.5 MAF**	**63.9-69.4% of 1921-** 1978 normal=10.8 MAF
Mean Spring RDO	2.3-2.5 MAF (38,653-42,014 cfs)	64.1-69.6% of 1921-1978 normal=3.6 MAF
Total Annual RDO	17-19 MAF	62.5-69.8% of 1921-1978 normal=27.2 MAF
Total Winter RDO	8.5-9.5 MAF	61.5-68.7% of 1921-1978 normal=13.8 MAF
Total summer-autumn RDO	1.6-2.0 MAF	62.0-77.5% of 1921-1978 normal=2.6 MAF

(The monthly distribution of regulated outflows may differ from seasonal averages, especially for winter and spring, **provided that volumes are sufficient to maintain optimal balanced** water quality conditions for different waater users regardless of year-type.)

Methods for Achieving Recommended Flows

(1) Rescheduling and reducing seasonal water diversions. For the spring, especially May and June, provide for the release to the Delta and Bay of volumes equal to at least 75% probability of exceedance for at least 2-3 years.

(2) Accumulation during the winter of sufficient water to provide flows adequate for maintaining or improving conditions for Delta and Bay water quality and living resources, especially when regulated river inflow and Delta outflow both correspond to lower than subnormal seasonal wetness.

(3) Seasonal redistribution of runoff more closely resembling natural patterns which are now distorted by reduction of spring flows and artificial increases in late summer and fall vflows.

(4) Re-examine plan to increase Delta pumping capacity since it is likely that export levels during the past decade have been 3-5 times greater than the volume of the Delta. Current exports already exceed the volume of the San Joaquin River outflow and may be responsible for serious reverse flows in the Delta, resulting in salt intrusion and decline in Delta water quality.

(5) Evaluate the potential value of water conservation, recycling, and increased efficiency of use (industrial, agricultural and municipal), marketing and trading for reducing demand before increasing entitlements or devloping new facilities.

(6) Utilize dry creek beds as retarding basins or increase storage capacity of existing reservoirs to accumulate part of wet year surplus winter and spring flows for discharge to the Delta and Bay in dry years. Such flows would be reserved to maintain adequate conditions for repelling salt intrusion, flushing, fish migration and spawning, and improving water quality. Such a program should be undertaken only after statutory or legislative controls are in place guaranteeing that the reserved flows are <u>not for export</u>.

The scientific and technical information submitted to the State Water Resources Control Board as exhibits for the Bay-Delta Hearings represents a wide range of data, evaluations and recommendations. Because of the lack of agreement among the many exhibits, it is recommended that the State Board request that this body of information be subjected to an exhaustive, independent evaluation by a neutral body of experts such as the National Research Council of the National Academy of Sciences. (Hearing Record, 12/9/87, pages 50-54)

M. Rozengurt

Michael A. Rozengurt | Michael J. Herz | Sergio A. Feld

February 1, 1988

STATEMENT

The Restraining Channel that Can Avert Salinization of Sacramento - San Joaquin Delta under Current and Planned Freshwater Diversions.

Abstract from invitational presentations at International meetings at Water Symposium -97 (Sweden, Stockholm) and the American Institute of Hydrology: *Agonizing Watershed-Coastal Seas Ecosystems: Critical Review of Alternatives.*

COMMON REMARKS.

Cumulative effects of inland water withdrawals of millions of acre feet have resulted in chronic depletion of the spring runoff ranging from -35 to -90%, as opposed to its natural ±25 to 30% of the perennial norm (average more than 55 years) that have Notably increased an anomalous predominance of years of subnormal wetness or critical dry regardless of watershed runoffs despite unimpaired runoff normalcy. Runoff depletion has resulted in an impeded functioning of a river-coastal ecosystem continuum accompanied by the salinization of the surface and ground water supply as well as the loss of millions of tons of oxygen, organic and inorganic matter, and sediments vital to the survival of deltas-coastal ecosystems the world over. This has triggered accumulation of entropy whose visible indicators are: salt intrusion into the deltas, increase detention time of natural and man-induced pollutants, hypoxia and anoxia (in summer particularly), eutrophication, and a precipitous decline of commercial and recreational catches of valuable fish. In short, man's perceived needs have ignored the scales of ecological tolerance and limitations of ecosystems and have created the new, artificial environment on a global scale, namely: **"the impounded river-delta-estuary-coastal seas."** A massive salt accumulation in formerly fresh and brackish water bodies has degraded their quality and accelerated the despoliation of habitats (example: the Mediterranean Basin, west Pacific, north and central Atlantic, etc.)

BACKGROUND.

Estuaries are the intermediate, complex link within delta- coastal sea ecosystems where continual variable confluence, interaction and mixing processes between river flow (delta outflow) and seawater inputs takes place. These processes result in the development of specific mixed water masses and, related to them, spatio -temporal distribution of their regime and biochemical characteristics which provide for the unique diversities and biological productivity of estuarine organisms.

Thus, the major factors controlling brackish water regimes of estuaries are the volume of fresh and salt water participating in the exchange between a river and sea. These regime elements as well as tide oscillations and winds are the moving forces, which are responsible for development of specific seasonal circulation patterns and surface, intermediate and deep layers The interaction between controlling factors and the moving forces determine the intensity of mixing, advection, and spatia-temporal distribution of hydrological and biological characteristics suitable the survival of the estuarine biota regardless of the unique hydrophysical, geophysical, and morphometric differences among estuaries.

For example, The Sacramento - San Joaquin unimpaired river spring discharges had been vital for preserving optimal hydrophysical and biological environment of the Delta - Bay ecosystem, for they had entrained many times the volume of estuarine brackish waters. This, in turn, had maintained a definite rate of salinity in the four transition zones in the Delta-Bay.

Historically, here, as in many other similar ecosystems, the deltaic zone had played and exclusive role as the heart of the entire coastal embayment. For normally rivers receive millions of tons of elements from river watersheds and produces, circulates, and processes an additional organic and inorganic increment within its body which greatly influences the richness of estuarine habitats. That is why an excessive reduction of flows is one of major cause of pending piscatorial and other resources' despoliation of deltas and adjacent water bodies the world over.

STATEMENT. Cascade of dams and perennial diversions of freshwater has caused a number of negative impacts on the hydrochemical and biological status of the Sacramento-San Joaquin Delta of San Francisco Bay ecosystem. The average depletion of spring and annual runoffs to the Delta due to upper and low rivers, and deltaic diversions exceed **75** and **55%** of their corresponding norms (computed more than 55 years). As a result, the frequencies of occurrence of man-induced years of subnormal and critical anomalous wetness have increased several times regardless of volumes of would be unimpaired spring runoff (no dams and storage) The similar events have been typified the alteration of integrated annual river disharges.

At the same time, late summer- fall sanitary and agricultural releases have caused a new phenomenon, namely, the regulated runoffs have become almost equal or higher then the spring regulated runoff. Yet, this inverse, intra-annual redistribution of wetness, undocumented for unimpaired runoffs in recent historical time, has not brought any improvements in water quality or biological productivity of deltaic - estuarine ecosystem. On contrary, spring cumulative, chronic runoff deficits compounded by the Delta inner water conveyance facilities (about **200MAF**, and up to **600 MAF-** a total water withdrawals from the Bay balance over last 25 - 30 years) have futher aggravated the ecosystem regime and, both have made the delta environment broken. Subsequently, these irrevocable losses of freshwater have triggered a **massive landward marine water intrusion into the Bay and the Delta, for potential capacity of remnants of regulated runoff to repulse a salty water have diminished. This has put the operation of fresh water intakes as well as the nursery ground of deltaic- upper Bay water body in peril.**

At present, these and other negative regime modifications have already caused the deterioration of water quality and a dramatic drop in migration, spawning, breeding, and catches of valuable semi-anadromous and anadromous fish.

Statement of Issue or Problem: The intrusion of sea water into estuaries and river deltas has become a major cause of salinization of delta-estuary ecosystems in the United States and throughout the world. Increasing amounts of fresh waters are being diverted from rivers and deltas for agricultural, municipal and industrial uses and thus, estuaries such as San Francisco Bay have experienced up to a 65 percent loss in fresh water inflows which used to serve to "flush" the Bay from salt accumulated in the basin due to sea water intrusion and agricultural and municipal drainage water discharges. Increases in salinity adversely affect fish spawning, nursery and habitat areas. Fresh water withdrawals also modify velocity distributions in in the waterways, thus altering patterns of sediment transport and pollutant dispersion; drinking water supplies are also affected as brackish water moves inland to fill adjacent wells and fresh water aquifers; and agricultural production is negatively impacted as reduced quality of irrigation water leads to the loss of croplands.

With the inevitable increase in water consumption in the rivers' watershed, and the deepening of shipping channel in the northern part of San Francisco Bay, adverse impacts of salty water intrusion into the Delta will become even more acute (especially in summer). Therefore, in the absence of radical, immediate remedial measures the continuation of salt accumulation in the upper Bay and southern part of the Delta will lead eventually to the elimination of the Delta's agricultural, industrial, and municipal water supplies intakes, living resources, and trigger a massive erosion of Delta levees.

The case of San Francisco Bay is a typical example of such development. Since 1944 nearly 400 million acre-feet of water has been diverted from the Sacramento-San Joaquin Delta resulting in salt water intrusion into the Delta. Thus, the quality of agricultural water derived from the Delta has declined significantly. Furthermore, Contra Costa County which pumps its water supply for over 300,000 residents from the Delta has experienced a serious decline in the quality of their drinking water. The increase in salinity and decreased flows to San Francisco Bay has also seriously affected the fisheries in the region. Sport catches of salmon, striped bass and shad have declined to as little as 10-30 percent of levels of 20 years ago despite a great increase in sport fishing effort, improved treatment of sewage discharges, and massive hatchery releases.

Other estuaries/deltas that have experienced degradation problems due to salt water intrusion include the Mississippi River Delta where salt water has recently intruded as far upstream as the intakes for New Orleans' water supply. Texas lagoons/estuaries have also experienced a serious water quality decline due to salt water intrusion as have the Nile River in Africa and the Sea of Azov in the USSR.

The purpose of the investigation proposed herein is to develop one specific solution concept for the restraining of salinity in estuaries: the Salinity Restraining Channel (SRC). Preliminary studies have shown that the SRC can be an effective, non-intrusive method of preventing salinity from reaching unacceptable levels. The channel operates on the basis of well defined hydraulic principles and is compatible with natural fish migration, sediment load transport and navigation requirements.

The proposed channel (figures 1,2) will have walls above the high-high tidal level and will be built with a channel width and depth that is suitable for navigation. The overall hydraulic resistance of the channel can be increased by induced turbulence and enhanced energy dissipation through the emplacement of certain structures on the bottom and walls of the structure.

GOAL. In order to preserve the impaired but reasonable salinity balance of the Delta - Suisin Bay the following solution is proposed: to built in the operational shipping channel in the northern or southern part of Suisun Bay or in San Pablo Strait the salinity restraining channel (SRC) as a means of protecting the Sacramento - San Joaquin Delta or upper San Francisco Bay and the Delta in particular, from further degradation due to salt intrusion.

Preliminary studies, based on SRC patent (attached, 1974) have shown that the SRC can be an effective, non-intrusive method of preventing salinity from reaching unacceptable concentration in fresh water bodies. It should be emphasized that the Hydrodynamics Institute of the Academy of Sciences of the Ukrainian Republic executed in 1973 numerous tests on a physical model of the Dniester estuary where a salt intrusion substantially degraded water quality of the Dniester delta and its fishery. It was demonstrated that salt intrusion for the Dniester estuary can be reduced by several times if SRC of the length about two miles will be built into the existing shipping canal (Rozengurt et al., 1978).

OBJECTIVES. Some of the benefits associated with the development of SRC will be :
(1) reduce the intensity and the probability of occurrence of saltwater intrusion in the Delta as much as three to five and more times, and preserve fresh water surplus of adjacent wells and aquifers,
2) enhance water quality for inner conveyance facilities and deltaic irrigation network,
(3) provide a tolerant environment for fish, and
(4) the open connection necessary for recreational boating and commercial shipping.

Project description. The **SRC** is relatively simple in concept, consisting of two constraining walls, extending above the high tide (see attached drawing), and have the current width and depth that is suitable for navigation. the desirable intensity of Delta Regulated Outflow entrainment and mixing of landwater and its final salt concentration can determine the length of the SRC walls. Note that **since time immemorial** the **Delta Outflow Hydraulic Head** have been responsible for ”producing” and maintaining the **Hydrostatic Pressure and Hydraulic Gradient** that construed a ***natural fresh and brackish water seaward barriers*** against an aggressive, landward intervention along the shipping channel much denser, marine water into a significant part of an estuary and the Delta.

The **SRC** can substantially reduce the salt concentration of avant- and delta water body on the basis of above-mentioned, well defined hydraulic properties of river emptying in coastal embayments, for normally the highest percentage of much less dense, delta outflow tends to gush through the shipping channel then over surrounding shallows. However, under conditions of permanent runoff depletion the hydraulic gradient have been gradually dwindling and, as a result, the underlying, much dense, estuarine landward flux has managed to fill in the significant volume of the shipping channel and even spill over its submersible walls and spread over the Bay’s shallows.

Therefore, the major task of the **SRC** will be to partially restore, under conditions of runoff regulations, the reasonable hydraulic head at the deltaic side at least during April-May-June flooding in order to enforce the repulsion of salt wedge from the Delta and Susuin Bay shipping channel. In this case , the **SRC** can maintain optimal hydrological regime compatible with a natural scheme of water and salt exchange between adjacent basins, and provide the remnants of sediment transport, fish migration, and navigation requirements. The main effect can be accomplished by narrowing the channel while allowing it significant length. Still certain techniques could be found to increase overall efficiency of the structure without affecting its discharge capacity.

Note that the overall hydraulic resistance of the **SRC** can be increased by intensified turbulence and salt water flux energy dissipation through the displacement of small structures on the bottom or slightly protruding plates from its walls. Since the SRC will be a passive structure not requiring energy or a special personal, it would have no associated operating costs. The approximate length of a channel of about two to four miles can effectively resist salt intrusion in avant-delta and Suisun Bay.

CONCLUSION.

In our view, any statement claiming that it is possible to restore a historical deltaic water quality or population of estuarine-dependent fish should be considered erroneous, for neither historical (unimpaired) runoff, nor historical migration routes are available for spawning and fish maturity. **We can not restore but we can mitigate the existing problems for years to come**.

The proposed SRC (a total cost of construction would be not less then $15 -25 million**)** could give water management a flexible opporunity to the planning water storage and conveyance facilities out of the Delta, which, at the same time, in concert with SRC can ensure the enviromental, economic, and societal concerns of Northern California about the enhancement and preservation of water quality and living resources of the Delta- Bay.

This solution might serve the many different interests concerned with the enhancement and conservation of the Delta ecosystem without disrupting agriculture, fishery, and recreational and commercial navigation, and will serve the needs of both Northern and Southern California. The proposed project will require the expenditure of approximately $100,000 for hydraulic evaluation of SRC different versions.

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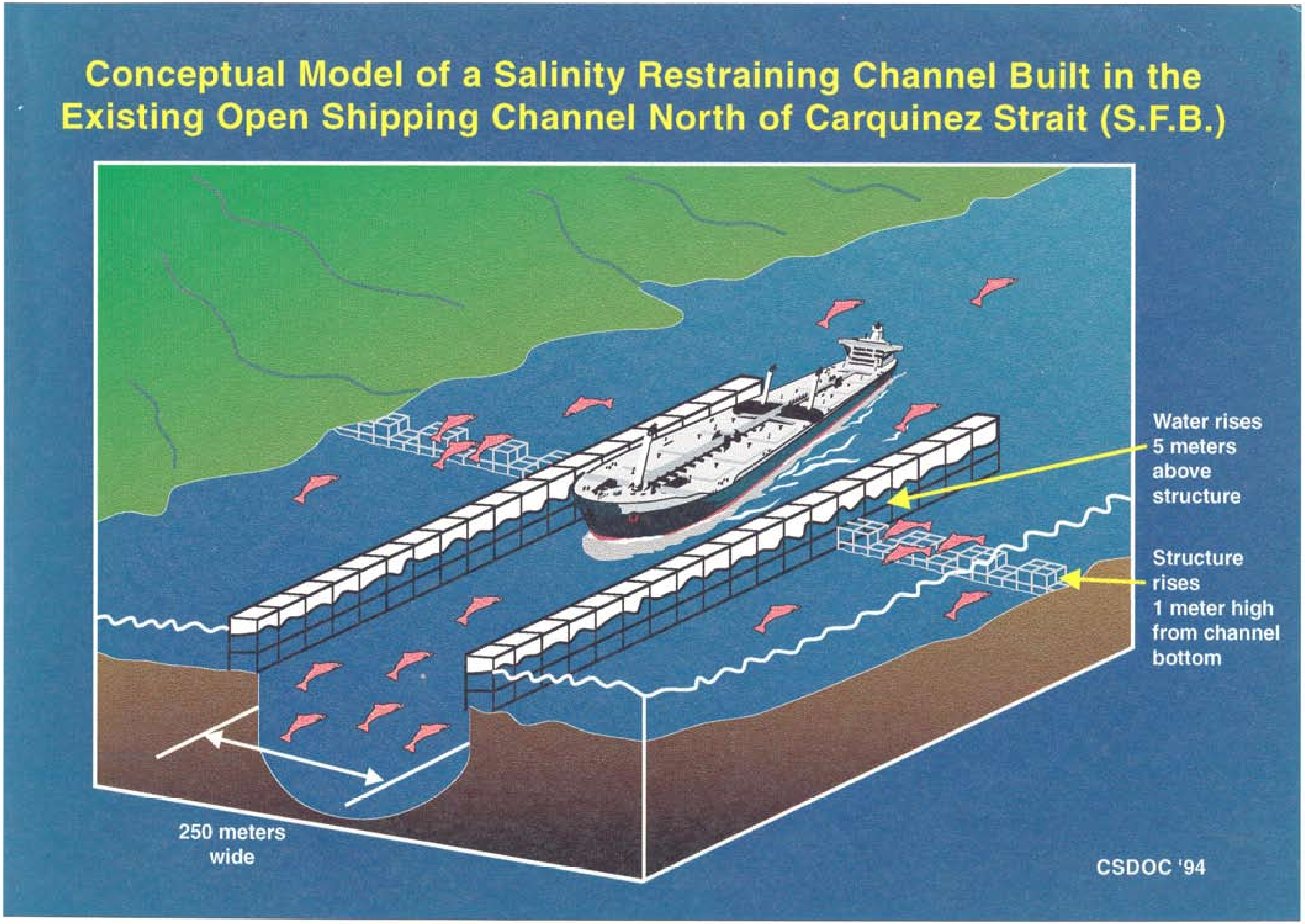
Conceptual Model of a Salinity Restraining Channel Built in the Existing Open Shipping Channel North of Carquinez Strait (S.F.B.)
Water rises 5 meters above structure
Structure rises 1 meter high from channel bottom
250 meters wide
CSDOC '94

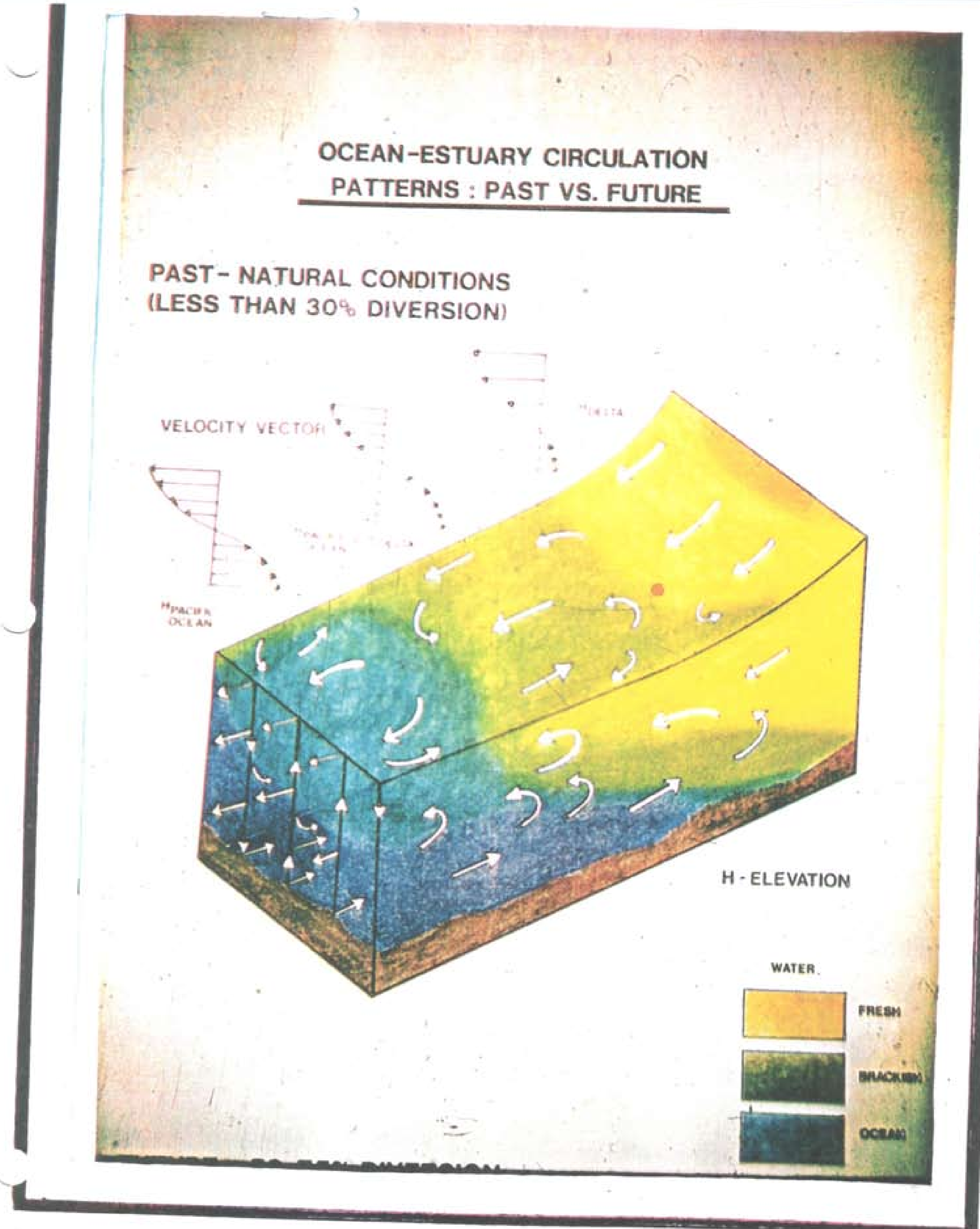
OCEAN-ESTUARY CIRCULATION
PATTERNS : PAST VS. FUTURE
PAST- NATURAL CONDITIONS
(LESS THAN 30% DIVERSION)
VELOCITY VECTOR
H-ELEVATION
WATER
FRESH
BRACKISH
OCEAN

Figure 2